ECE 120 Second Midterm Exam
Spring 2017

Tuesday, March 14, 2017

Name: ______________________________ NetID: ______________

Discussion Section and TA Name:

9:00 AM	[ ] AB1 Rui	
10:00 AM	[ ] AB2 Rui	
11:00 AM	[ ] AB3 Matt	
12:00 PM	[ ] AB4 Pawel	
1:00 PM	[ ] AB5 Pawel	
2:00 PM	[ ] AB6 Gowthami	[ ] ABA Huiren
3:00 PM	[ ] AB7 Gowthami	[ ] ABB Huiren
4:00 PM	[ ] AB8 Yu-Hsuan	[ ] ABC Sifan
5:00 PM	[ ] AB9 Yu-Hsuan	[ ] ABD Surya

- **Be sure that your exam booklet has 10 pages.**
- **Write your name and netid and check your discussion section on this page.**
- **Do not tear the exam booklet apart, except for the last two pages.**
- **Use backs of pages for scratch work if needed.**
- **This is a closed book exam. You may not use a calculator.**
- **You are allowed one handwritten 8.5 x 11" sheet of notes (both sides).**
- **Absolutely no interaction between students is allowed.**
- **Clearly indicate any assumptions that you make.**
- **The questions are not weighted equally. Budget your time accordingly.**
- **Show your work.**

Problem 1	18 points	____________
Problem 2	16 points	____________
Problem 3	16 points	____________
Problem 4	16 points	____________
Problem 5	18 points	____________
Problem 6	16 points	____________

Total 100 points ____________

Problem 1 (18 points): K-maps and Don’t Cares

Consider the 4-variable function `F(A,B,C,D)`, with the following K-map (drawn twice). **Note:** there are extra copies of this K-map on the last page of the exam. Use them for scratch work, but they will NOT be graded. Make sure that you mark the two K-maps below correctly.

Minimal SOP

`F(A,B,C,D)` CD

AB	00	01	11	10
00	0	X	1	X
01	1	0	X	1
11	1	0	X	1
10	X	X	1	0

Minimal POS

`F(A,B,C,D)` CD

AB	00	01	11	10
00	0	X	1	X
01	1	0	X	1
11	1	0	X	1
10	X	X	1	0

1. **(4 points)** Give a **minimal SOP** expression for `F(A,B,C,D)` and show the corresponding loops on the **left map**.

   Minimal SOP: **`F(A,B,C,D)=`**____

2. **(5 points)** Is the solution to part 1 unique? If it is not, write a different minimal SOP solution.

   Circle one: **UNIQUE** **NOT UNIQUE**

   If not unique, write a different minimal SOP solution (but do not mark the loops):

   Minimal SOP: **`F(A,B,C,D)=`**____

3. **(4 points)** Give a **minimal POS** expression for `F(A,B,C,D)` and show the corresponding loops on the **right map**.

   Minimal POS: **`F(A,B,C,D)=`**____

4. **(5 points)** Is the solution to part 3 unique? If it is not, write a different minimal POS solution.

   Circle one: **UNIQUE** **NOT UNIQUE**

   If not unique, write a different minimal POS solution (but do not mark the loops):

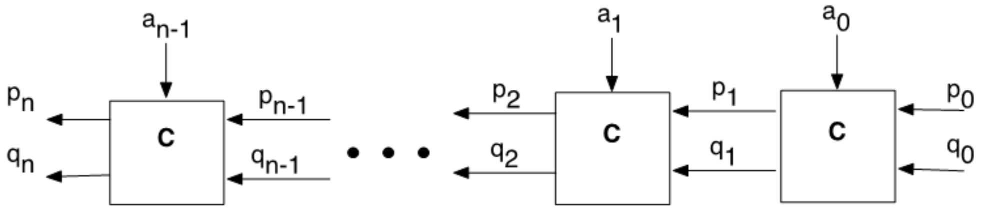
   Minimal SOP: **`F(A,B,C,D)=`**____

Problem 2 (16 points): Bit-Sliced Design

Let A = $a_{n-1} \ldots a_2a_1a_0$ be an **n-bit input**. In this problem you will design a circuit which outputs **p_n = 1** if A contains two **consecutive** 1s.

For example, for n = 5: if A = 10010, then p_5 = 0; if A = 01101 or A = 01111, then p_5 = 1.

Your implementation should use the array shown below, which consists of n identical copies of a network C. C has inputs a_i and carry-in bits p_i and q_i. C has outputs p_{i+1} and q_{i+1}.



1. The carry bits are used to convey information from one stage to the next. We need 3 such "messages" and will use $p_{i+1}q_{i+1}$ = 00, 01, and 1x (where x denotes "don't care"). Explain in words the meaning of each $p_{i+1}q_{i+1}$ carry ($p_{i+1}q_{i+1}$ = 01 has been provided).

p_{i+1}	q_{i+1}	Meaning
0	0	
0	1	11 has not been detected and a_i=1
1	x	

2. Specify the p_0 and q_0 values: p_0 = ____________ and q_0 = ____________

3. Fill in the K-maps below for p_{i+1} and q_{i+1}.

		p_iq_i			
		00	01	11	10
a_i	0				
	1				

p_{i+1}

		p_iq_i			
		00	01	11	10
a_i	0				
	1				

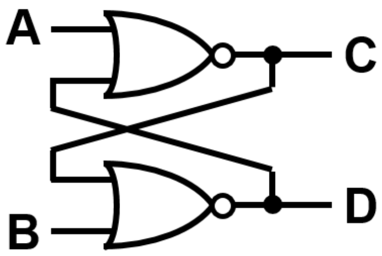
q_{i+1}

Problem 3 (16 points): Sequential Feedback Circuits and Multiplexers

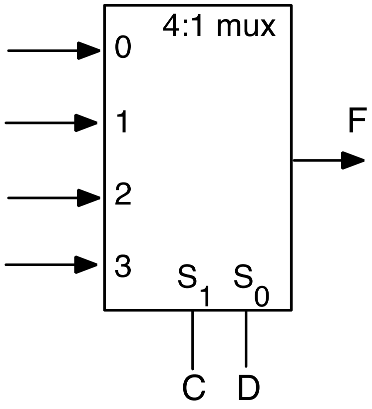
1. **(8 points)** For the circuit below, fill in the table with all stable configurations of the outputs C and D for each possible combination of inputs A and B. **Use only as many rows as necessary.**

   Write only 0s and 1s in the boxes.

A	B	C	D



2. **(8 points)** Consider function F(A,B,C,D) as defined in the following K-map. Implement F using **only** the multiplexer given below. **You may not add any components, nor any additional gates.** Complemented inputs are **not** available.



CD

AB	00	01	11	10
00	0	x	1	x
01	1	0	x	1
11	1	0	x	1
10	x	x	1	0

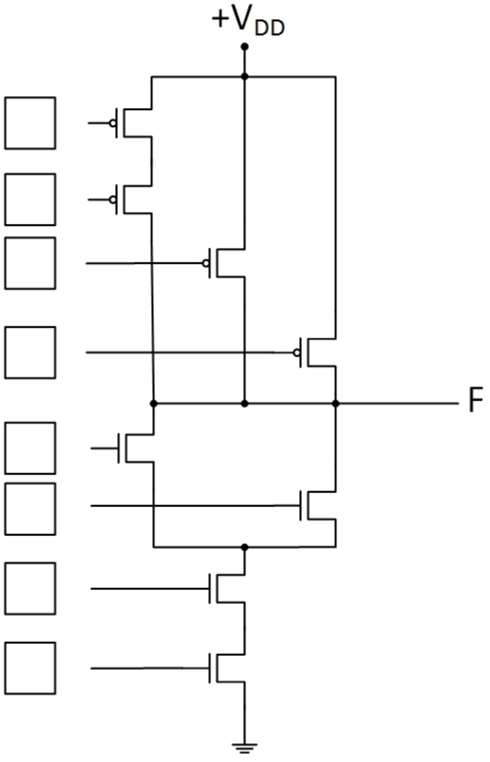
F(A,B,C,D)

Problem 4 (16 points): CMOS Gates, Boolean Expressions and 2-Level Design

1. **(8 points)** The transistor-level circuit below implements the logic equation:

$$F = \overline{(A + B)CD}$$

Label the inputs to all transistors by filling in the boxes.



2. **(4 points)** Write the truth table for a function Z(X) that takes a 3-bit unsigned integer input X=$x_2x_1x_0$ and outputs a 2-bit unsigned integer Z=z_1z_0. The output Z is the remainder after dividing X by 3. In other words:

Z = X % 3

For example, if X=5, then Z=2. Describe the behavior of your system as a truth table.

x_2	x_1	x_0	z_1	z_0
0	0	0		
0	0	1		
0	1	0		
0	1	1		
1	0	0		
1	0	1		
1	1	0		
1	1	1		

3. **(4 points)** Implement the function

G=(Q+W)E’(R+Q)

as a **2-level NOR-NOR** circuit using the **minimum** number of gates. Complemented inputs are available.

Problem 5 (18 points): Basic Registers

1. **(6 points)** Suppose a 3-bit register initially stores $Q_2Q_1Q_0$ = 101 and in the next clock cycle, the register has the values $Q_2Q_1Q_0$ = 110. Which of the following operations could the register be implementing?
   Circle **ALL** possible answers.

   No change

   Parallel load

   Clear

   Flip all bits

   Shift right

   Circular shift right

   Logical shift right

   Arithmetic shift right

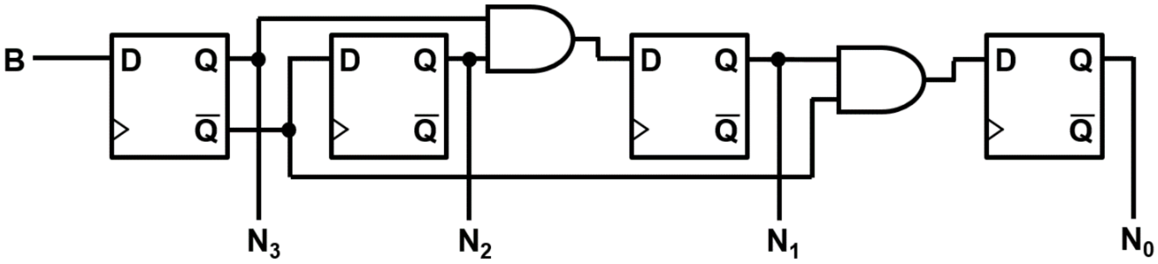
   Shift left

   Circular shift left

   Logical shift left

   Arithmetic shift left

2. **(12 points)** Consider the register below, which is constructed from four positive-edge-triggered D flip-flops and two gates. A serial input B is fed into the leftmost flip-flop, and the values of all flip-flops can be read in parallel as the output $N=N_3N_2N_1N_0$. **All four flip-flops share a common clock signal (not shown in figure to reduce clutter).**



Assume that $N_3N_2N_1N_0$ are unknown at the start of operation (that is, in clock cycle 0) and that input B is set to the sequence 0, 1, 0, 1 (from clock cycle 0 to 3). Fill in the values of $N_3N_2N_1N_0$ for clock cycles 2 to 4 in the table below. If a particular bit's value is not possible to know, write "unknown."

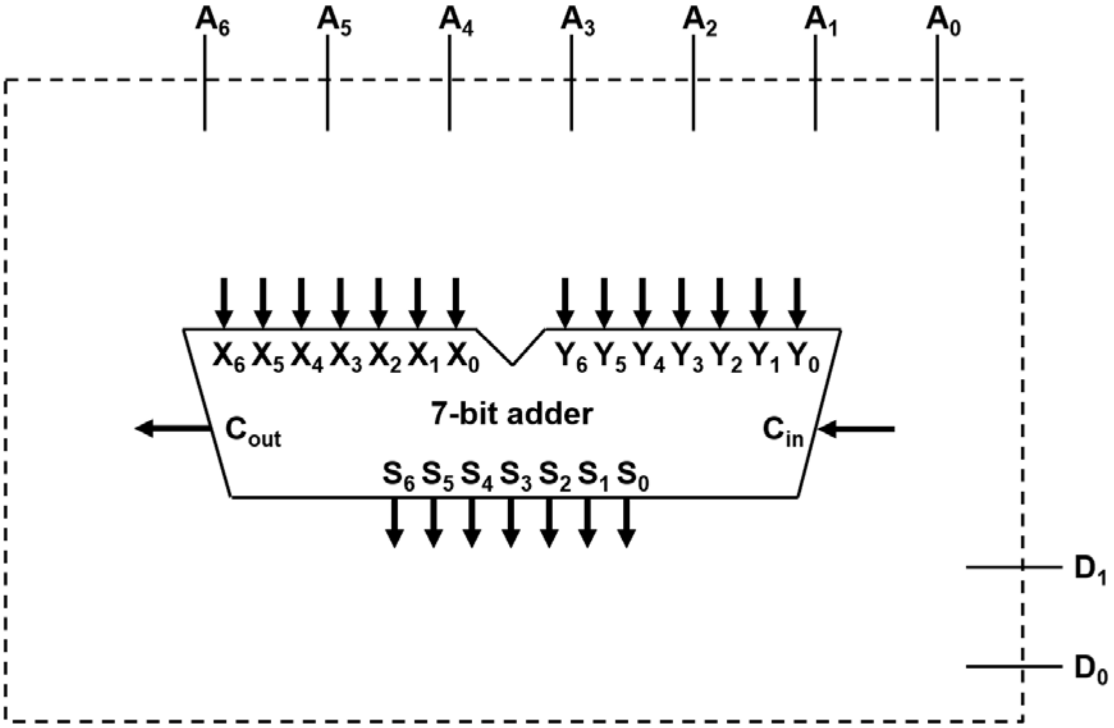
	B	N_3	N_2	N_1	N_0
cycle 0	0	unknown	unknown	unknown	unknown
cycle 1	1	0	unknown	unknown	unknown
cycle 2	0				
cycle 3	1				
cycle 4	unknown				

Problem 6 (16 points): Building with Components and Abstraction

Prof. Lumetta needs your help. The lines at Daily Byte café have grown too long, and he needs your assistance in developing appropriate technological advances to aid the baristas. A barista is a person who makes caffeinated beverages, arguably the second-most important job in the world (after engineer).

1. **(8 points)** Prof. Lumetta has some 7-bit adders sitting around from an old class. He wants you to incorporate one into your solution for this problem. Given an ASCII character $A=A_6A_5A_4A_3A_2A_1A_0$ representing a digit from '1' (x31) to '4' (x34), calculate a 2-bit drink code $D=D_1D_0$ according to the table below. You may use the bits of character A as well as 0s and 1s to produce D. **You may not add any components, nor any additional gates.**

A	D_1D_0
'1'	00
'2'	01
'3'	10
'4'	11



(This problem continues on the next page.)

Problem 6, continued:

2. **(8 points)** Prof. Lumetta needs some logic to manage the various liquid dispensers. There are four liquids to be dispensed, each controlled by one output bit. E is for espresso, M is for steamed milk, F is for foamed milk, and C is for chocolate. A drink is made by dispensing combinations of these four liquids for two cycles, as shown by the table below.

	latte D_1D_0=00	mocha D_1D_0=01	cappuccino D_1D_0=10	macchiato D_1D_0=11
cycle N=0	E, M	E, M, C	E, F	E
cycle N=1	E, M	E, M	E, F	F

Each column in the table shows the liquids that must be dispensed for the two cycles needed to create a drink. For example, for a macchiato, the drink code is D_1D_0=11. In this case, in cycle N=0, espresso alone must be dispensed (so E=1 while M=0, F=0, and C=0), and in cycle N=1, foam alone must be dispensed (so F=1 while E=0, M=0, and C=0).

Given a 3-to-8 decoder with inputs wired to cycle number N (most significant bit), D_1, and D_0 (less significant bits), add **ONE INVERTER** and **TWO GATES OF YOUR CHOICE** (AND, OR, NOT, NAND, NOR, or XOR) to produce the signals C, E, F, and M that control the output of the four liquids.

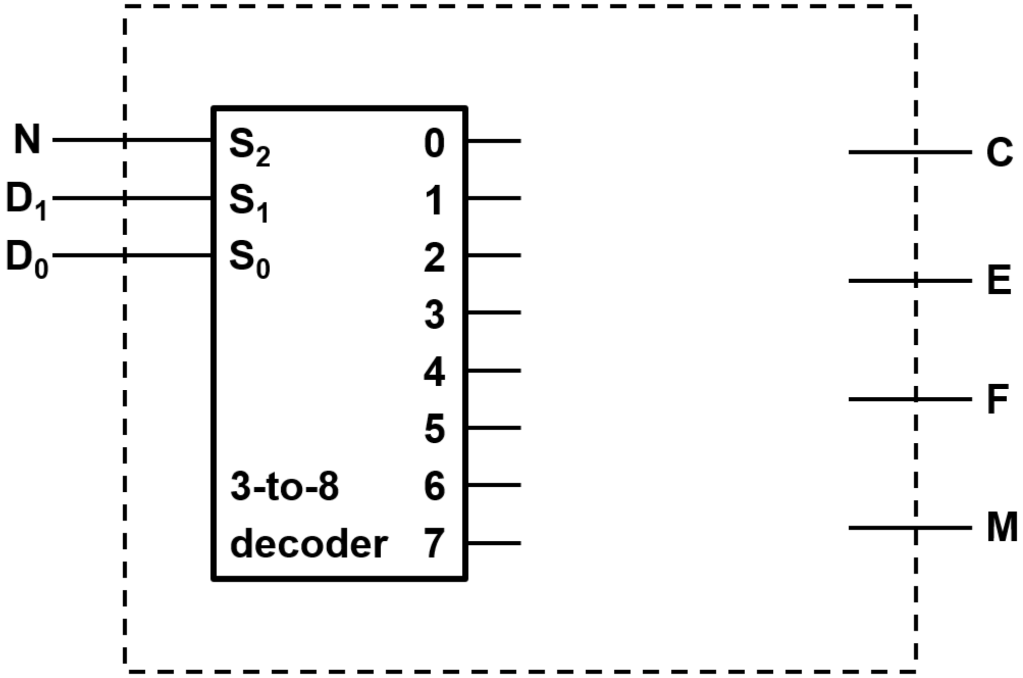


Table of ASCII Characters

```
Char Dec  Hex | Char Dec  Hex | Char Dec  Hex | Char Dec  Hex
(nul)  0  00  | (sp) 32   20  | @    64   40 | `    96   60
(soh)  1  01  | !    33   21  | A    65   41 | a    97   61
(stx)  2  02  | "    34   22  | B    66   42 | b    98   62
(etx)  3  03  | #    35   23  | C    67   43 | c    99   63
(eot)  4  04  | $    36   24  | D    68   44 | d    100  64
(enq)  5  05  | %    37   25  | E    69   45 | e    101  65
(ack)  6  06  | &    38   26  | F    70   46 | f    102  66
(bel)  7  07  | '    39   27  | G    71   47 | g    103  67
(bs)   8  08  | (    40   28  | H    72   48 | h    104  68
(ht)   9  09  | )    41   29  | I    73   49 | i    105  69
(lf)  10  0a  | *    42   2a  | J    74   4a | j    106  6a
(vt)  11  0b  | +    43   2b  | K    75   4b | k    107  6b
(ff)  12  0c  | ,    44   2c  | L    76   4c | l    108  6c
(cr)  13  0d  | -    45   2d  | M    77   4d | m    109  6d
(so)  14  0e  | .    46   2e  | N    78   4e | n    110  6e
(si)  15  0f  | /    47   2f  | O    79   4f | o    111  6f
(dle) 16  10  | 0    48   30  | P    80   50 | p    112  70
(dc1) 17  11  | 1    49   31  | Q    81   51 | q    113  71
(dc2) 18  12  | 2    50   32  | R    82   52 | r    114  72
(dc3) 19  13  | 3    51   33  | S    83   53 | s    115  73
(dc4) 20  14  | 4    52   34  | T    84   54 | t    116  74
(nak) 21  15  | 5    53   35  | U    85   55 | u    117  75
(syn) 22  16  | 6    54   36  | V    86   56 | v    118  76
(etb) 23  17  | 7    55   37  | W    87   57 | w    119  77
(can) 24  18  | 8    56   38  | X    88   58 | x    120  78
(em)  25  19  | 9    57   39  | Y    89   59 | y    121  79
(sub) 26  1a  | :    58   3a  | Z    90   5a | z    122  7a
(esc) 27  1b  | ;    59   3b  | [    91   5b | {    123  7b
(fs)  28  1c  | <    60   3c  | \    92   5c | |    124  7c
(gs)  29  1d  | =    61   3d  | ]    93   5d | }    125  7d
(rs)  30  1e  | >    62   3e  | ^    94   5e | ~    126  7e
(us)  31  1f  | ?    63   3f  | _    95   5f |(del) 127  7f
```

Boolean algebra properties

Commutativity	x·y = y·x	x + y = y + x
Associativity	(x·y)·z = x·(y·z)	(x + y) + z = x + (y + z)
Distributivity	x·(y + z) = x·y + x·z	x + y·z = (x + y)·(x + z)
Idempotence	x·x = x	x + x = x
Identity	x·1 = x	x + 0 = x
Null	x·0 = 0	x + 1 = 1
Complementarity	x·x’ = 0	x + x’ = 1
Involution	(x’)’ = x	
DeMorgan’s	(x·y)’ = x’ + y’	(x + y)’ = x’·y’
Absorption	x·(x + y) = x	x + x·y = x
No-Name	x·(x’ + y) = x·y	x + x’·y = x + y
Consensus	(x+y)·(y+z)·(x’+z) = (x+y)·(x’+z)	x·y + y·z + x’·z = x·y + x’·z

Extra copies of K-map for problem 1 (use as scratch copies, we will NOT grade them)

F(A,B,C,D) CD

AB

	00	01	11	10
00	0	X	1	X
01	1	0	X	1
11	1	0	X	1
10	X	X	1	0

F(A,B,C,D) CD

AB

	00	01	11	10
00	0	X	1	X
01	1	0	X	1
11	1	0	X	1
10	X	X	1	0

F(A,B,C,D) CD

AB

	00	01	11	10
00	0	X	1	X
01	1	0	X	1
11	1	0	X	1
10	X	X	1	0

F(A,B,C,D) CD

AB

	00	01	11	10
00	0	X	1	X
01	1	0	X	1
11	1	0	X	1
10	X	X	1	0

F(A,B,C,D) CD

AB

	00	01	11	10
00	0	X	1	X
01	1	0	X	1
11	1	0	X	1
10	X	X	1	0

F(A,B,C,D) CD

AB

	00	01	11	10
00	0	X	1	X
01	1	0	X	1
11	1	0	X	1
10	X	X	1	0